TIME SERIES ANALYSIS OF VLBI ASTROMETRIC SOURCE POSITIONS AT 24-GHZ

D.A. BOBOLTZ[1], A.L. FEY[1] & The K-Q VLBI Survey Collaboration
[1] U.S. Naval Observatory
3450 Massachusetts Ave., NW, Washington, DC, 20392-5420, USA
e-mail: dboboltz@usno.navy.mil, afey@usno.navy.mil

ABSTRACT. To date there have been 10 VLBI experiments observed over a period spanning 5 years and analyzed for the purpose of establishing a high-frequency (24 GHz) reference frame. The database now contains information on 274 sources and a total of 1052 images. From the data, we have produced a high-frequency astrometric catalog of 266 sources. Of these 266 sources, 88 of them have been observed in at least five epochs. We produced time series of source positions for each of the 88 sources and compare source position variations at 24 GHz with variations in the same sources at X band. Here we discuss the astrometric catalog, the stability of the sources at 24 GHz, and the possible implications for ICRF2.

1. INTRODUCTION

As part of a collaborative effort to extend the International Celestial Reference Frame (ICRF) to higher radio frequencies, we have observed a number of extragalactic sources at Q band (43 GHz) and K band (24 GHz) using the 10 stations of the Very Long Baseline Array (VLBA) operated by the National Radio Astronomy Observatory (NRAO). The long term goals of this program are: 1) to develop a high-frequency celestial reference frame (CRF) with a variety of applications including improved deep space navigation, 2) to provide the astronomical community with an extended catalog of calibrator sources for VLBI observations at 24 and 43 GHz, and 3) to study source structure and source stability at these higher frequencies in order to improve the astrometric accuracy of future reference frames.

Thus far, 10 epochs of observations have been taken over the course of 5 years from 2002–present. All 10 of these epochs included observations at 24 GHz. Additionally, in four of the 10 epochs, observations were also recorded at 43 GHz. The details of the observations, calibration, and data processing up to the production of an experiment database readable by the Calc/Solve software package will be discussed in a forthcoming paper (Lanyi et al. 2008). In these proceedings, we concentrate on the 10 K-band experiments only. In §2 we discuss the astrometric catalog produced from the K-band observations and compare source positions with several other catalogs. In §3 we describe the process of generating position time series for those sources observed in five or more epochs and the relevant source stability information available from the series.

2. ASTROMETRIC CATALOG OF SOURCE POSITIONS

To generate the astrometric catalog of source positions, we used the Calc/Solve software package maintained by the NASA Goddard Space Flight Center (GSFC). The 10 diurnal K-band experiments encompassed 82,354 measurements of bandwidth synthesis (group) delay and phase delay rate. Parameters estimated per session include twenty-minute piecewise linear continuous troposphere parameters; tropospheric gradients in the east-west and north-south directions, linear in time, estimated every six hours per 24-hr session; quadratic clock polynomials for the gross clock behavior; and sixty-minute piecewise linear continuous clock parameters. No ionosphere calibration was applied. ITRF2000 was used as a priori station positions and velocities. USNO Bulletin A was used for a priori Earth Orientation Parameters (EOP). Positions of the 266 sources having three or more measurements of group delay were the only global parameters and were linked to the ICRF by constraining the right ascension and declination zero points to those of the ICRF Defining sources (Ma et al. 1998). The weighted rms residuals of the resulting solution were 17.24 ps in group delay and 47.25 fs/s in phase delay rate.

The CRF resulting from this astrometric solution was compared to several existing X-band catalogs including USNO's latest solution, crf2007b (`http://rorf.usno.navy.mil/solutions/crf2007b/`), the

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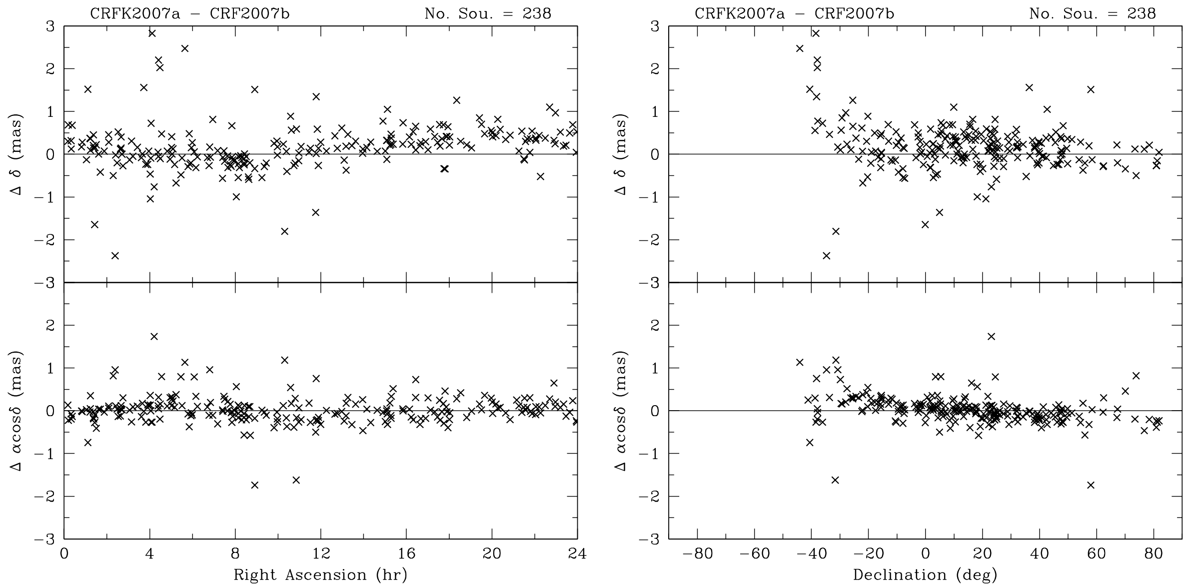

Figure 1: Source position differences ($\Delta\ \alpha\cos\delta$ and $\Delta\ \delta$) for the 237 sources in common between the crfk2007a (K-band) catalog and the crf2007b (X/S-band) catalog plotted as a function of right ascension (*left*) and declination (*right*).

ICRF catalog of defining sources (Ma et al. 1998), and ICRF Extensions 1 and 2 (Fey et al. 2004 and references therein). Shown in Figure 1 are the position differences in right ascension ($\Delta\ \alpha\cos\delta$) and declination ($\Delta\ \delta$) between crfk2007a and crf2007b plotted as a function of right ascension (*left*) and declination (*right*). There were a total of 238 overlapping sources between the two catalogs. The weighted mean position differences are 1 μas in $\Delta\ \alpha\cos\delta$ and 119 μas in $\Delta\ \delta$. The weighted root-mean-square (wrms) standard deviations of the position differences are 184 μas and 276 μas in $\Delta\ \alpha\cos\delta$ and $\Delta\ \delta$, respectively. From the plot, we also observe that any systematic effects between the two catalogs as a function of right ascension or declination appear to be small.

Listed in Table 1 are several additional catalog comparisons that were made. Each group of two rows shows the crfk2007a positions differenced with three variations of the ICRF catalog and, for comparison purposes, the USNO crf2007b catalog differenced with the same ICRF catalogs. The second column of the table shows the number of matching sources between the two catalogs being compared. Columns 3–6 list the weighted mean and wrms standard deviation of the position differences between the two catalogs being compared. These results indicate that relative to the ICRF, the K-band catalog is comparable to the X-band catalog. Although there are many fewer sources available in the K-band catalog, values for the wrms are at most a factor of 2.8 worse that those for the X-band catalog and are at best roughly equivalent.

Table 1: Comparison of Catalog Source Position Differences

Catalogs	Num. of Matching Sources	$\Delta\ \alpha\cos\delta$ Wt. Mean (μas)	$\Delta\ \alpha\cos\delta$ WRMS (μas)	$\Delta\ \delta$ Wt. Mean (μas)	$\Delta\ \delta$ WRMS (μas)
crfk2007a - ICRF Def.	77	−55	259	+80	353
crf2007b - ICRF Def.	212	−2	221	+8	255
crfk2007a - ICRF Ext. 1	192	−46	284	+80	337
crf2007b - ICRF Ext. 1	667	−21	180	−10	343
crfk2007a - ICRF Ext. 2	199	+4	199	+31	239
crf2007b - ICRF Ext. 2	717	+24	75	−33	84

3. TIME VARIATION OF K-BAND SOURCE POSITIONS

Time variation of the astrometric coordinates of CRF sources has been attributed to variability of their intrinsic structure (e.g. Fey, Eubanks & Kingham 1997). To investigate the stability of the high-frequency CRF source positions, we performed several astrometric solutions similar to that from which the astrometric catalog was derived. The difference here is that some fraction of the sources are treated as "arc" parameters (i.e. an estimate of the position was derived for each session in which the sources were observed). The estimation of source position stability was limited to 88 sources that were observed in five or more of the 10 VLBA epochs. Five epochs was considered a sufficient number of sessions (position estimates) per source to derive reliable statistics. Thus, an additional five astrometric solutions, with parameterization identical to the CRF solution described in §2, were produced. In each of these solutions, positions of approximately one fifth of the 88 sources were treated as "arc" parameters. The remaining sources in these five solutions were treated as global.

Shown in Figure 2 are the distributions of the wrms position variations in right ascension and declination from USNO solution crfk2007a position time series. For comparison, Figure 3 shows the distributions of the wrms position variations from the USNO X-band solution crf2007b position time series (`http://rorf.usno.navy.mil/solutions/crf2007b/`). Each distribution shows only the 67 sources that are common to both solutions. Shown in each figure are the mean and median wrms position variation for the 67 sources. Mean K-band position variations of ∼0.15 and ∼0.29 mas were found in right ascension and declination, respectively. For comparison, mean X-band position variations of ∼0.24 in right ascension and ∼0.33 mas in declination were determined for the same 67 sources. These results seem to indicate that the astrometric variations are smaller for sources at K-band versus X-band. The one caveat to this result is that the X-band variations include a much longer time history (back to 1979) and many more epochs of observations. A study, yet to be performed, will be to compute the X-band stability using 10 equivalent X-band experiments as was done for the catalog comparison described above.

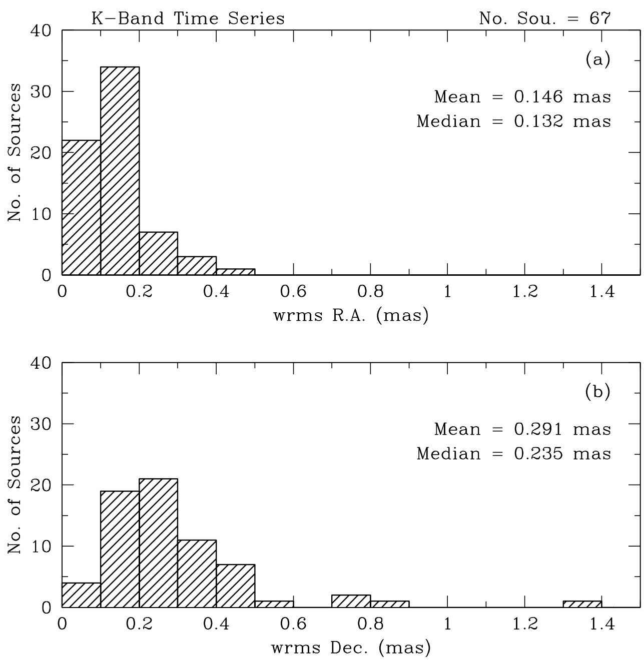

Figure 2: Distribution of the weighted rms position variation from USNO solution crfk2007a position time series for 67 K-band sources in a) Right Ascension and b) Declination.

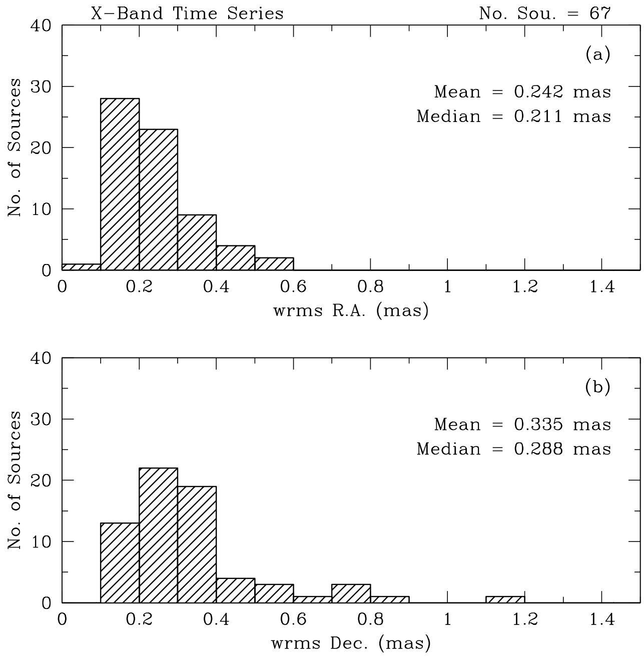

Figure 3: Distribution of the weighted rms position variation from USNO solution crf2007b position time series at X-band for the same 67 sources as shown in Figure 2. The two panels show the distribution in a) Right Ascension and b) Declination.

4. CONCLUSIONS

We have used the 10 high-frequency reference frame VLBA experiments recorded to date to produce an astrometric catalog of positions for 266 sources at 24 GHz. We find that this K-band catalog, while not yet at the precision of the best X-band catalogs, shows potential for future incorporation into the ICRF. In addition, we have produced time series of astrometric positions for 88 of the 266 catalog sources that were observed in five or more epochs. Preliminary results from these time series seem to indicate that the astrometric variations are smaller for sources at K-band versus X-band. This is again a promising sign for a future high-frequency celestial reference frame.

5. REFERENCES

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